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ATMOSPHERIC ELECTRICITY

By P. A. Sheppard, B.Sc.

Of all meteorological phenomena the thunderstorm is perhaps the most impressive and awe-inspiring, and it was with the thunderstorm that the study of atmospheric electricity began when Benjamin Franklin and others demonstrated the similarity between lightning and the electric spark produced in a laboratory. The thunderstorm preserves its position to-day as a subject for study in the modern field of atmospheric electricity, not only because of its intrinsic interest and unsolved problems but on account of the important part it appears to play in the electrical characteristics of the atmosphere in fine weather as well as in thundery areas.

The major problem of atmospheric electricity, progress towards the solution of which has been considerable in the last two decades, is to discover the mechanism whereby the negative charge, which resides on the earth's surface in fine weather areas, is maintained against the positive ion conduction current flowing from the air to the ground and tending always to annihilate the charge on the ground. Alternatively and more fully stated, a difference of potential, E, of about one million volts,

exists between the upper conducting atmosphere and the ground due to a separation of charge. On account of the small though by no means negligible conductivity of the intervening atmosphere this separation of charge tends continuously to be nullified by the air-earth current, i, of fine weather areas, given by Ohm's law, $i = E/R$, where R is the effective total resistance between the ground and the upper conducting atmosphere. The problem presented is then to discover a charge separation process (positive charge upward, negative downward) which effectively counterbalances the downwardly directed stream of positive charge and so maintains the electric field of fine weather areas.

It was first suggested by C. T. R. Wilson that the origin of the required charge separation process (or processes) is to be found in regions of disturbed weather. It has long been known that rain is in general electrically charged, and most observers agree that a preponderance of positive charge is transferred from air to earth by this means. Thus the " precipitation " current due to rain is on the whole in the same direction as the fine weather conduction current. In thunderstorms, however, there are additional types of charge transference which may play a major role in the atmospheric electric balance. These are:—

(i) lightning discharges between the cloud and the ground, and between the cloud and the upper atmosphere,

(ii) point discharge currents between pointed objects on the ground (grass blades, bushes, trees, etc.), and the air above—occasionally visible, when it is termed St. Elmo's Fire,

(iii) ionic conduction currents between the cloud and the ground, and between the cloud and the upper atmosphere.

In order that these agencies shall maintain the fine weather field they must on the whole bring negative electricity to the ground and positive electricity to the upper atmosphere. This can only be the case if the polarity of the thundercloud is positive, i.e. positive

charge at the top of the cloud and negative at the bottom. The importance of determining the general polarity of thunderclouds, and of obtaining a quantitative measure of the three types of charge transference enumerated above, is, therefore, apparent.

The results of several workers show that thunderstorm clouds are mainly of positive polarity, though this is not to say that the cloud base is wholly negative and the cloud top wholly positive. Further, the charge transference occasioned by lightning flashes has been measured by means of the electric field changes which they produce, and continuous records of point discharge current have been obtained. These measurements all go to show that the thunderstorm is quite capable of producing the flow of charge required to counteract the fine weather flow. As an example of the balance sheet which may be drawn up, a table, due to Wormell (1), is given below, for a square kilometre of ground at Cambridge.

	Coulomb/sq. km./annum.
By natural point discharge current	- 100
By lightning	- 20
By ionic conduction current ...	+ 60
By precipitation current	+ 20
Net flow of charge to ground ...	- 40

Such an estimate is only very rough, but it shows that in this locality the four processes may balance or even give rise to an excess negative charge. It is to be noted that the charge transference produced by thunderclouds is not confined between cloud and ground but may be equally active in passing positive charge from cloud to upper atmosphere.

Thus the thunderstorm (or shower cloud, not necessarily producing thunder) may be regarded as an electrical generator which transports positive charge from the ground and supplies it to the conducting layers of the high atmosphere, where it is rapidly distributed so as to maintain those levels at an approximately constant potential of about a million volts. From time to time

during the life of this generator its internal resistance, generally high on account of the immobilisation of ions by attachment to cloud droplets, may be less than that of the " external circuit ", i.e. from cloud to ground and from cloud to upper atmosphere. If a sufficient voltage difference has been generated by the cloud the generator may then be " short-circuited " by a lightning flash passing from pole to pole of the cloud. A highly schematic picture of these charge transference processes is given in Fig. 1.

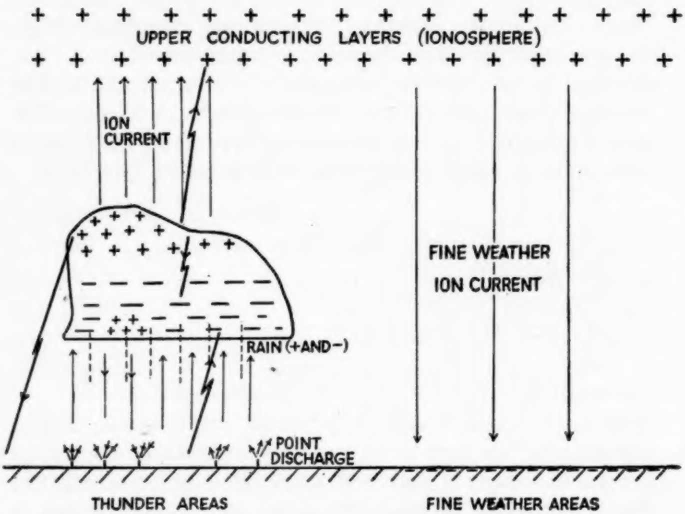

FIG. 1.—THE CIRCULATION OF ELECTRICITY IN THE ATMOSPHERE. (SCHEMATIC.)

Lightning is shown by zigzag lines, ion current by vertical lines, point discharge by branched lines, and precipitation current by pecked lines. The arrows indicate the direction of positive charge transference.

If the above view be accepted certain consequences are to be expected in regard to the variation of the electric field in fine weather areas. When thunderstorms are most active the potential of the upper conducting

layers will be a maximum and this will be reflected in the magnitude of the fine weather field near the ground unless atmospheric pollution or other local influences exert a dominating effect. Whipple (2) has in fact shown that a marked parallelism exists between the diurnal variation in electric field strength over the oceans and in the Arctic and the diurnal variation in thunderstorm activity integrated over the whole globe. (Fig. 2.)

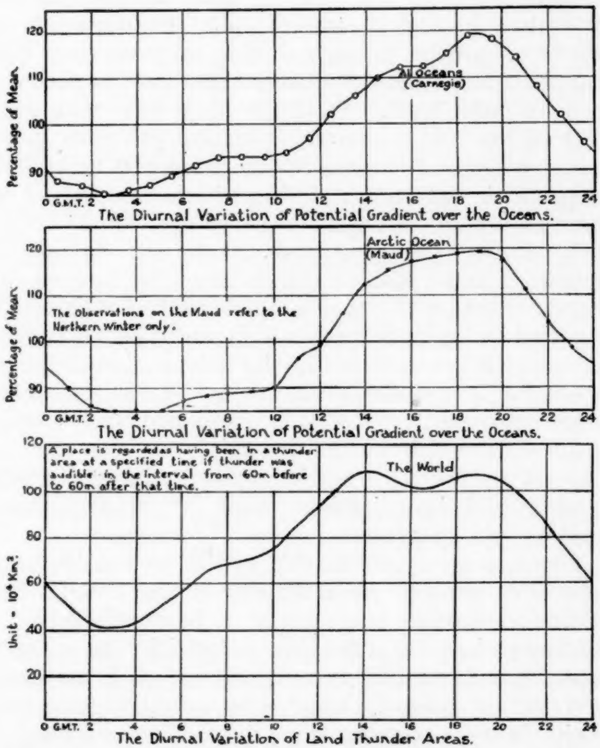

FIG. 2.—A. VARIATION OF POTENTIAL GRADIENT WITH UNIVERSAL TIME. (UPPER TWO CURVES.)

B.—VARIATION OF THUNDERSTORM ACTIVITY OVER THE EARTH'S SURFACE. (LOWER CURVE.)

The charge circulation process described above is thus able in a general way to account for the maintenance of the earth's electric field. The important question of the mechanism whereby the charge separation is brought about is not yet, however, completely answered. Of recent investigations the most significant is that of Simpson and Scrase(3) who explored the charge distribution below, in, and above thunderclouds by means of sounding balloons which carried an original type of potential gradient recorder. Their results are consistent with those of earlier ground observers that thunderclouds are mostly of positive polarity, but in addition they found that the main region of charge separation is above the freezing point level. From this they infer that one at least of the major charge separation processes is connected with the frictional charge developed by colliding ice particles. Electric field observations in clouds of drift snow show that considerable charge separation occurs in such clouds. Simpson and Scrase also found local centres of large positive charge near the base of some thunderclouds, which they attribute to the positive charge acquired by water drops when disrupted by an air blast. The possible processes giving rise to ionisation and charge separation in thunderclouds are not, however, confined to the two mechanisms already mentioned, and it remains a question which of the possible processes are most responsible for the electric fields produced. Further experimental investigations must be made before a solution can be given.

There is no space in this article to consider other aspects of atmospheric electricity in any detail. Some additional features may, however, be mentioned.

Observations in atmospheric electricity have, in the past, most frequently been concerned with the electric field near the ground. This has been a rather unfortunate choice in some respects, since the field is here markedly controlled by the electrical characteristics of the atmosphere near the ground. On this account the more fundamental variations in the fine weather field, as shown e.g. in Fig. 2, were for long obscured. The more

fundamental entity is the air-earth current, which, controlled by the potential difference between the ground and the upper conducting layers and by the total effective resistance of the atmosphere between these levels, shows much smaller local influence than does the field. The current, under equilibrium conditions, must be the same at all heights, whilst the electric field at any height adjusts itself to the value of the resistance at that height.

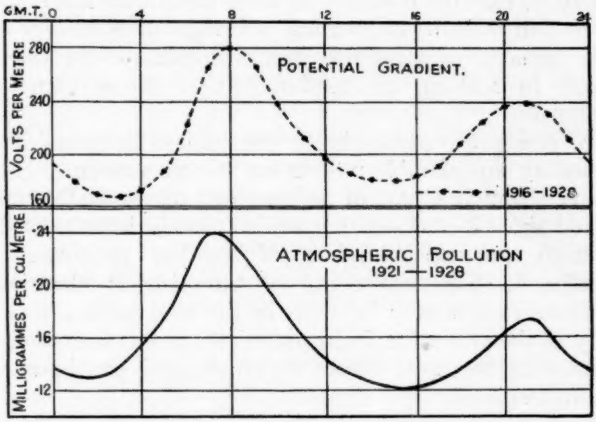

FIG. 3.—DIURNAL VARIATION OF POTENTIAL GRADIENT AND OF ATMOSPHERIC POLLUTION IN SUMMER AT KEW OBSERVATORY.

Continuous records of field strength are, however, much more easily obtained than those of current, and it has been of interest to see how the variations of field strength in urban areas may be accounted for by a combination of the effects of atmospheric pollution production (more strictly, sub-microscopic nuclei) and wind turbulence. Diurnal variation in the rate of production of nuclei and in atmospheric diffusion together

give a curve for diurnal variation in the concentration of nuclei near the ground, which is in very marked sympathy with the diurnal curve of field strength, as shown by Whipple(4) for Kew. (Fig. 3.)

The conductivity of the atmosphere arises from ionising radiations having their origin in the earth's crust (earth radiation), in the air (air radiation), and in outer space (cosmic radiation). Near the earth's surface, except over the sea, the main source of ionisation is earth and air radiation, whose intensities vary with locality, with state of surface and other meteorological factors. It may be that the intensity of these radiations has some connection with the enervating or invigorating quality of local climate; at least this factor should not be overlooked in seeking an explanation of these climatic differences.

To conclude, atmospheric electricity is a subject possessing considerable interest on its own account. It is also very much a part of meteorology as normally considered since it and weather are so closely inter-related. Certainly an understanding of weather processes is essential to the unravelling of atmospheric electrical problems and it may be that, in the reverse sense, the study of the subject will aid materially in our knowledge of some of the more direct meteorological problems of our atmosphere.

References.

(1) Wormell, T. W. London, *Proc. roy. Soc. A*, 1930, 127, p. 589.

(2) Whipple, F. J. W. London, *Quart. J. R. Met. Soc.*, 1929, 55, p. 1.

(3) Simpson, Sir G. C., and Scrase, F. J. London, *Proc. roy. Soc. A.*, 1937, 161, p. 309.

(4) Whipple, F. J. W. London, *Quart. J. R. Met. Soc.*, 1929, 55, p. 351.

REMARKABLE PRESSURE FLUCTUATION IN THE VALE OF YORK

By R. G. Veryard, B.Sc.

At 7h. G.M.T. on February 12th, 1939, the synoptic report from Catterick gave the pressure reduced to sea-level as 1005·6 mbs. and the wind as W by S, force 8, i.e. gale force. Since this pressure did not seem to fit with the general run of the isobars it was thought that the barometer might have been read incorrectly, and the reading was therefore not published in the British Section of the *Daily Weather Report*. An examination of the barograph chart from Catterick showed, however, that the pressure of 1005·6 mbs. was quite correct and that as reported by the observer, there had been a fall of 6 mbs. between 4h. and 7h. G.M.T. The anemograph also confirmed the westerly gale which lasted for more than an hour.

Fig. 1 shows the pressure distribution over the British Isles at 7h. G.M.T. on February 12th, after isobars have been drawn to conform as accurately as possible to all the available data. It will be seen that there is a small low-pressure system in the Vale of York with its centre a little to the north of Catterick.

At first it was thought that the drawing of the isobars over Durham and north Yorkshire as a trough might be the correct solution. There was a strong westerly gradient and it was not unreasonable to consider whether, in these circumstances, the chain of the Pennines, which runs mainly north and south, might not account for a trough of low-pressure on the lee-side, such a trough being not uncommon with a strong wind blowing at right angles to a range of hills. An examination of the barograph chart from Tynemouth showed, however, that such

a drawing of the isobars would have been incorrect since the pressure there did not fall below 1008 mbs. at or about

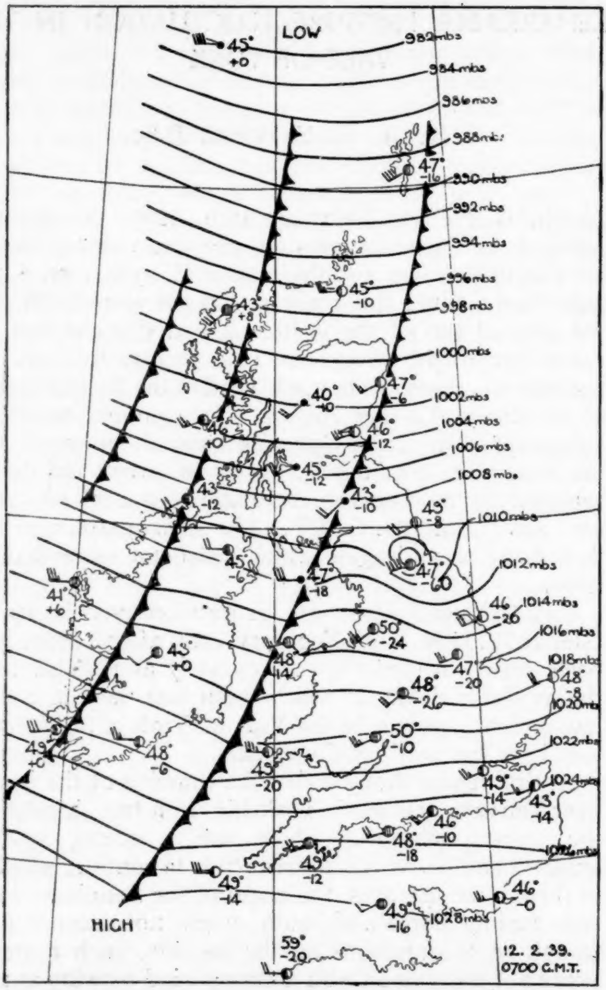

FIG. 1.—PRESSURE DISTRIBUTION OVER THE BRITISH ISLES AT 7H. G.M.T. ON FEB. 12TH, 1939.

the time in question. On the other hand, the anemograph chart from Durham shows that the wind was from a westerly point all the morning. The closed isobars must therefore have embraced a very small area. Unfortunately, no useful observations are available for the area between Catterick and Durham, but barograph charts from Dishforth and Linton-on-Ouse confirm the existence of the low-pressure system to the south of Catterick.

Charts of recording instruments from stations to the west of Catterick were carefully examined to see whether the disturbance could be identified on the windward side of the Pennines but the result was negative; neither was any indication found of the persistence or development of the disturbance in an easterly direction. There is little doubt, therefore, that this small rotary system had a very short life and that it was formed " locally ", i.e. on the lee side of the Pennines.

On February 11th, a cold front passed across the British Isles bringing in its wake a stream of rather unstable polar air. Pressure, which had been falling ahead of this front, steadied and rose temporarily with the passage of the front but then continued its downward path ahead of a secondary cold front which at 7h. G.M.T. on the 12th extended, approximately, from the east coast of Scotland through the Isle of Man to St. George's Channel. (At the same time there was a second but less well defined minor cold front along the west of Scotland and probably a third about 90 miles farther to the west.) This secondary cold front passed through Catterick, at least at the surface, between 9h. and 9h. 30m. G.M.T.: Fig. 2 shows the relevant portions of the autographic records at Catterick. It will be noted that the passage of the front was not accompanied by any noticeable drop of temperature at the surface. (The upper air temperature observations at Aldergrove show a fall of five to six degrees up to about 10,000 feet between 7h. 45m. on the 12th and 7h. 15m. on the 13th—see Fig. 3.) At Durham a sudden fall of 2° F. occurred at 9h. 30m.; there was also a sharp drop of temperature with the passage of the

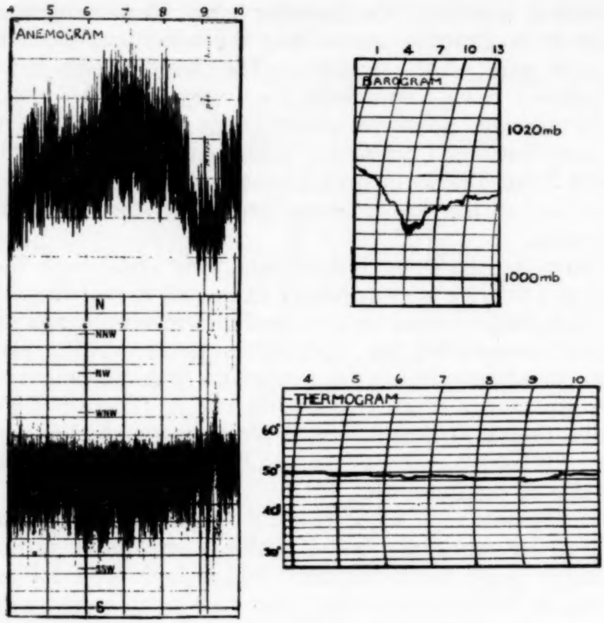

FIG. 2.—AUTOGRAPHIC RECORDS AT CATTERICK, FEB. 12TH, 1939.

front at Dun Fell in Durham, 2,735 ft. above M.S.L. Light showers occurred just ahead of the front at Catterick but none in the immediate rear of the front because, presumably, the lower layers of the air over Catterick were then descending*.

The observations at Catterick show that at no time was the sky completely overcast. At 7h. there were seven to eight tenths of strato-cumulus cloud, before 8h. a layer of alto-cumulus appeared, and cumuli-form cloud, both low and medium, persisted behind the front, although after its passage at the surface the amount of

* Very squally showers of rain, hail and snow were experienced over the Pennines.

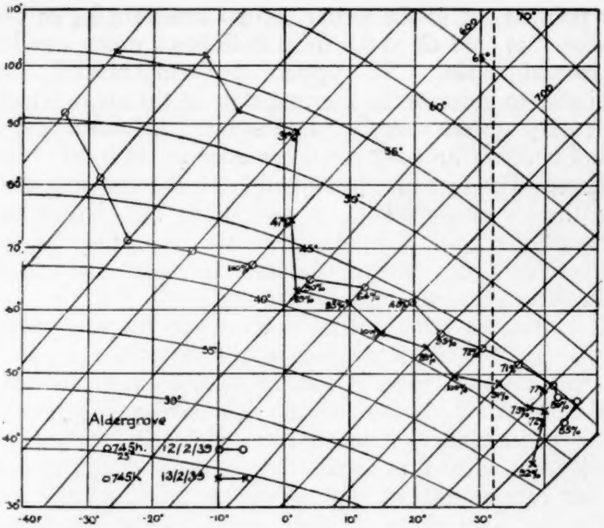

FIG. 3.—UPPER AIR TEMPERATURES AT ALDERGROVE.
FEB. 12TH, 1939, 7H. 45M. to FEB. 13TH, 1939, 7H. 15M.

low cumulus cloud decreased to less than four tenths. Similar conditions were observed at Linton-on-Ouse to the south and at Acklington to the north. An indication that the small low-pressure system was very shallow is given by the barogram from Ampleforth which showed a fall of 2 mbs. only, between 4h. and 7h. compared with 6 mbs. at Catterick during the same period. Ampleforth, which is 25 miles east-south-east of Catterick, is over 400 feet above sea level. At 9h. a pilot balloon ascent was made at Catterick and the observations revealed winds of 65 km/hr. from 270° at 1,000 metres, 100 km/hr. from 260° at 500 metres, and 50 km/hr. from 260° at the surface. Pressure ceased to fall at Catterick at 7h., rose slightly for about 2 hours and then jumped by more than 2 mbs. in a few minutes.

It is tempting to imagine that by 7h., the " nose " of the cold air had advanced across the Pennines to a point almost above Catterick, but, as Mr. C. K. M. Douglas

has pointed out to the writer, actual overhanging of the " nose " of cold air at the front itself has a much smaller horizontal scale. No upper air temperatures are available to indicate the thermal state of the air in which the rotary system actually formed, but it is known that a fall of temperature aloft often precedes a cold front at the surface. The fact that there had been showers indicates that the air was unstable, or potentially so. Hence the overrunning cold air, or, shall we say, the fall of temperature up above, would increase the local instability of the air over the Vale of York.

It is therefore thought that this instability was partly responsible for the formation of the disturbance. It is known that small rotary systems often form in unstable air but as yet there has been no detailed investigation of these phenomena. Such an investigation cannot be carried out without adequate data and the data required in this case would, in view of the small size of the disturbance, necessitate a close net-work of observing stations and adequate upper-air as well as surface observations. Unfortunately, the data available are very scanty.

An important but not the sole cause of the phenomenon would appear to have been the effect of the hills in producing eddies. It is suggested that, in this connection, the work of Fujiwhara (1) who observed the behaviour of whirls in water, may furnish a clue to the formation of the small disturbance in question (although it is realised that Fujiwhara's work may not account for the formation of really large low-pressure systems). He found that small whirls tend to approach and amalgamate, giving larger whirls. The existence of eddies on the leeward side of hills is very well known. The work of Georgii and others (2) shows that the turbulence is most pronounced with strong winds and unstable air. Fig. 4 gives an idea of the position of

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(1) Brunt, D., " Physical and Dynamical Meteorology," 1934, pp. 300–1.

(2) Morgans, W. R., *Air Ministry R. & M. Report, No. 1456,* 1932, pp. 18–27.

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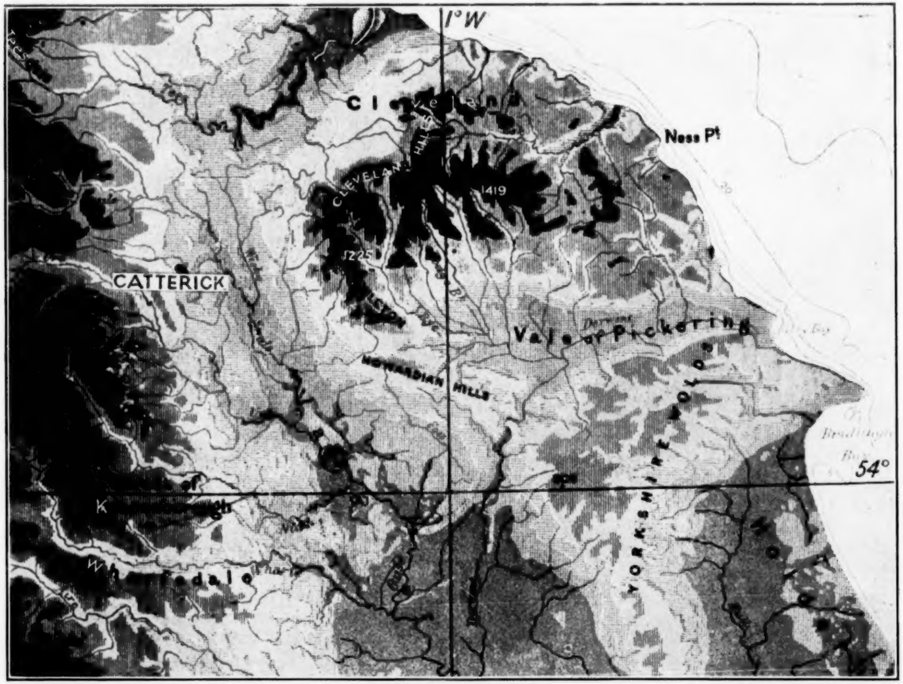

FIG. 4.—TOPOGRAPHY OF THE AREA AROUND CATTERICK.

Catterick in relation to the Pennines. It will be seen how the chain of hills is broken by the valleys of the Swale, Ure, and Nidd. There is little doubt that topography was a contributory factor in the formation of the whirl.

One may presume that the general fall of pressure ahead of the secondary cold front was due to divergence in the upper layers, but about one-half of the fall of pressure at Catterick must have been due to divergence associated with the whirl itself. That is to say, in addition to general convergence in the lower layers ahead of the front, there must have been local convergence associated, probably, with thermal convection. As the mechanism of these small rotary systems, embedded in a more or less solid current of air, is unknown and since adequate data are not available it is not possible to explain the actual eviction of air which must have taken place. One might say that the reduction of pressure at the core of the disturbance was due to spin, or vice-versa! Perhaps the theory of Durst and Sutcliffe (3) concerning the development of tropical revolving storms might apply in this case?

It would appear that the phenomenon in question is not entirely new to the Vale of York. Mr. Burridge, of the Catterick Meteorological Office states that, when there is a flow of unstable air from a westerly point, there is often a marked oscillation in the wind direction and velocity; in fact, the wind-vane sometimes makes several revolutions in quite a short period. An example of this is shown in Fig. 5 which gives a section of the anemograph charts for March 8th and 9th, 1938. These occasions were brought to the notice of the writer by Mr. F. Davies of the Dishforth Meteorological Office. Mr. Davies states that, when there is a westerly gradient, the force of the wind at the surface at Dishforth is often as much as the geostrophic wind-speed, or even a little more. He adds that on such occasions pilots have often reported

(3) Durst, C. S., and Sutcliffe, R. C., London, *Q. J. R., Meteor. Soc.*, 64, 1938, p. 75.

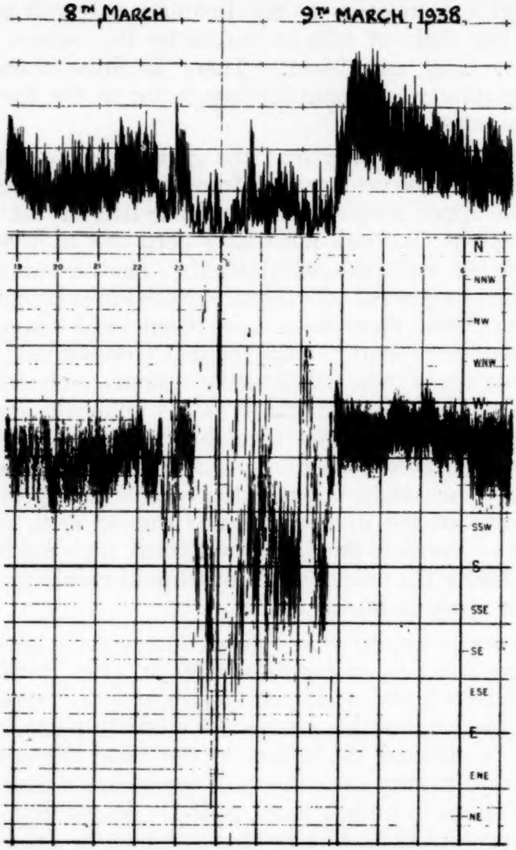

FIG. 5.—CATTERICK ANEMOGRAM.
MARCH 8TH, 1938, 19H. TO MARCH 9TH, 1938, 6H.

excessive bumpiness. It may be that, with westerly winds, the valleys such as Wensleydale which intersect the Pennines roughly from east to west produce some kind of funnel effect similar to that which is known to occur in the Firth of Forth.

LETTERS TO THE EDITOR

Circumzenithal Arc at Wittering, Northants

The circumzenithal arc was noted twice between February 17th and 19th, 1939. On February 17th at 11h. 20m. G.M.T. a sheet of thin alto-stratus was breaking up and a sheet of apparently very thin cirro-stratus could be seen. By 11h. 40m. G.M.T. the $22\frac{1}{2}°$ halo was visible with a well coloured parhelion to the left of the sun and a much fainter one to the right. The halo itself displayed faint colour effects only. A small upper portion of the 46° halo was also visible together with the circumzenithal arc (the latter being rather poor as regards colours). During the next hour the phenomena slowly faded with the exception of the circumzenithal arc—this gradually increased in its intensity and at 12h. 25m. G.M.T. was very brilliant against blue sky (the only cirro-stratus visible at this time being in another sector of the sky). The arc continued brilliant for another 15 minutes and was then obscured by the passage of lower cloud.

The second occasion was on February 19th between 12h. and 13h. G.M.T. In this case the sky was partly covered with thick and coarse looking bands of cirrus—no typical cirro-stratus could be seen. The $22\frac{1}{2}°$ halo was visible (as a whitish ring) with finely marked parhelia to the right and left of the sun (the colour effects were strong). A very faint upper portion of the 46° halo was noted at 12h. 45m. G.M.T. with a good circumzenithal arc, the latter showing strong colours. The whole phenomenon remained visible for some 20 minutes from 12h. 45m. and then quickly faded as the clouds thickened and fused together.

The circumzenithal arc was again noted on March 2nd. The time of the arc's appearance was 15h. 50m. A very small portion of the $22\frac{1}{2}°$ halo was also visible. The general conditions of the sky at the time of observation to-day were:—Alto-cumulus and alto-stratus with patches of lenticular alto-cumulus (the latter displaying subdued

irisation and resembling the rare nacreous clouds in the merging of the colours), these medium clouds covered some seven-tenths of the sky. There was however about two-tenths of striated cirro-stratus in which the circumzenithal arc was plainly visible for a period of ten minutes. The colours were of a moderate intensity.

W. F. WATSON.

Meteorological Office, Wittering, Northants.
March 2nd, 1939.

Cirriform Clouds observed in Southern Rhodesia

In connection with Mr. S. T. A. Mirrlees' article " Some unusual observations of cirriform clouds ", in this Magazine for November, 1938, similar clouds are illustrated in an article " The Contax and Cloud Study at Manila " by Rev. C. E. Depperman, S.J., published by Zeiss Ikon in *Photographie und Forschung,* October, 1936. In the discussion the author states—

" Attention is especially invited to the two Figures III and IV, in which we have profuse virgae *below* what seems definitely Alto-cumulus. Note that the virgae appear to be of Cirrus type, but yet Cirrus is formed of ice-crystals and Alto-cumulus of water droplets; how then could the ice-crystals be below the water droplets ? A possible explanation might be that the Alto-cumulus is just above a decided temperature inversion, the virgae just below; and hence the temperature below could be lower than that above; but the writer is inclined to believe that the virgae shown are formed of water droplets in spite of their delicate texture and are only a clever imitation of Cirrus virgae."

Similar phenomena were observed recently over a wide area of Southern Rhodesia. The cause appears to have been a stationary occlusion. A polar air outbreak had surrounded and was slowly lifting a body of moist equatorial air. Virga was seen below thick alto-stratus clouds for several days. The alto-stratus gradually thinned out and finally broke up into alto-cumulus on November 25th, virga still being present. An aeroplane flight by the Rhodesian Air Unit recorded a temperature

of 0° C. at 14,000 feet, and just reached the alto-cumulus level at 17,000 feet, where the temperature was – 5° C., but showing definite signs of an inversion. It therefore appears probable that the alto-cumulus cloud would be composed mainly of liquid and frozen water drops, while turbulence in the lower part of the cloud would result in the formation of ice crystals. Under these circumstances, one would expect both frozen water drops and ice crystals in the virga.

J. S. PEAKE.

Rhodesia Meteorological Service.
December 12th, 1938.

River Temperatures

On looking through the records of the temperature of the River Clwyd at Trefnant for last winter I came across the following facts.

At mid-day on January 6th, 1939, the temperature of the water was 33·9° F. The grass minimum temperature the previous night was 3° F. and the air temperature at mid-day had risen to about 26° F., as the thaw was approaching. There was some ice in the river which is very unusual owing to the rapid current. The air temperature reached 33° F. by 21h. on the same day, and it gradually rose until at mid-day on January 8th it was 52° F. At this hour the temperature of the river water was 47·2° F., a remarkable rise of 13·3° F. in 48 hours.

I should be glad if anyone could explain how such a big rise of temperature could take place. The river flooded very badly, but this was chiefly due to melting snow from the mountains, not to rainfall. As so much of the heat transferred from the warm air to the snow goes to provide the latent heat of the snow-water, I am at a loss to account for the large rise of temperature of that water in so short a time.

S. E. ASHMORE.

Llannerch Gardens, St. Asaph, Flintshire, North Wales.
April 14th, 1939.

NOTES AND NEWS

The First Pressure-Tube Anemometer.

Among recent acquisitions of the Science Museum is one of particular interest to meteorologists, namely the recording portion of a pressure tube anemometer, which is believed to be the first instrument of this type ever manufactured. The introduction of the pressure tube anemometer marked a new epoch in anemometry, as by its record of the gusts it enabled the detailed structure of the wind to be studied whereas former instruments which were almost exclusively of the " cup " type, gave the mean wind over a period only. In 1892 Mr. W. H. Dines described the principle of the pressure tube anemometer in the *Quarterly Journal of the Royal Meteorological Society,* and at about the same date the first instrument was set up in his house at Oxshott, Surrey, being subsequently transferred to Pyrton Hill, Oxfordshire, and later to Benson. The instrument was in continuous use for almost 40 years, after which it was stored until its presentation to the Science Museum by Mr. Dines' eldest son, Mr. L. H. G. Dines. The recorder was made by Mr. R. W. Munro, the founder of the present firm of that name, who collaborated with Mr. Dines in the design. It was not, unfortunately, given a serial number, and there is therefore no absolute proof that this was the first instrument manufactured. The indirect evidence however is very strong as there can be little doubt that Mr. Dines would have received the first instrument made by Mr. Munro for test before other instruments were made for sale. Another early instrument of similar pattern is to be found in the Meteorological Office Museum at South Kensington. This is probably the first pressure tube anemometer which was used by the Meteorological Office. One detail in its construction proves that it was of slightly later date than the one recently presented to the Science Museum. These old instruments differ from the modern pattern in that the buoyancy portion of the float surrounds the vertical cylinder instead of being contained within it. The float

is therefore of much larger diameter and the whole instrument more bulky. The velocity scale is identical, namely ·6 in. per 10 mi/hr. The pressure tube anemometer has, since its introduction, become known over almost the whole of the globe. It is in wide use in this country and in the Dominions and Colonies, while instruments have also been sold to many foreign countries.

J. S. D.

Royal Meteorological Society.

The usual monthly meeting of the Society was held on Wednesday, May 17th, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. F. J. W. Whipple, F.Inst.P., Vice-President, was in the Chair.

The following papers were read and discussed:—

The seasonal and geographical distribution of absolute drought in England.—By Miss L. F. Lewis, B.Sc.

Records at nine stations with long records show that a large number of absolute droughts is experienced in south-east England and the southern Midlands compared with north-east England, although the average annual rainfall is approximately the same in each case; a greater number of absolute droughts is recorded at Liverpool than at Stonyhurst, due to the shelter afforded to Liverpool from the moist south-west winds by the Welsh mountains and the greater height of Stonyhurst above mean sea level; a larger number of absolute droughts is experienced on the south-east coast than on the more unsettled south-west coast. The seasonal incidence of absolute drought is next investigated. The results are shown graphically on a single diagram, with the days of the year as abscissæ and the number of occasions of absolute drought as ordinates. Finally the odds to one against a "drought-day" (a day which has been included in a period of absolute drought) are evaluated for each calendar month at each station.

Evaporation over catchment areas, II.—By D. Lloyd, M.Eng.

Information has been extracted from Government sources relating to drainage areas situate in northern Italy. Values of general rainfall, loss and weather details are tabulated. The provisional formula, advanced recently to estimate the probable loss by evaporation over catchment areas, is applied to these data. The values of loss, expected on account of the weather and permeability of sub-surface, are shown to be of the right magnitude.

The distribution of wet-bulb potential temperature in four selected cyclones.—By A. M. Firesah, M.Sc.

The distribution of wet-bulb potential temperature has been investigated in four cyclones, each by means of serial sounding balloon ascents made at one station. The results are plotted

as though they represented observations along a vertical cross-section through the moving cyclone. Lines of equal wet-bulb potential temperature are drawn, and these are found to show a characteristic form of distribution at warm fronts, cold fronts and occlusions. At warm fronts the lines are closely crowded together. At cold fronts they show a nose raised some kilometres above the ground, the wet-bulb potential temperature decreasing with height in the air below the nose. The air in this region usually shows marked latent instability capable of being realised after only relatively small upward displacement. At occlusions the lines of equal wet-bulb potential temperature have a pronounced V-shaped form.

Magnetic Observations in Bavaria

In 1840 J. von. Lamont founded the Magnetic Observatory of Munich. Observations and investigations of terrestrial magnetism continued regularly until 1925, after which they have been carried on at a provisional magnetic observatory in Maisach. We learn from Dr. Friedrich Burmeister that this work will now be continued at the Observatory for Terrestrial Magnetism at Fürstenfeldbruck, 26 km. west of Munich. In February 1940 the centenary of the regular observation of terrestrial magnetism in Bavaria will be celebrated.

Auroral Notes for April 1939

Active aurora was seen on the nights of April 17th and 24th. For the night of the 17th the only report comes from Lerwick Observatory (Shetland). Coronae and pulsating surfaces were seen from 21h. 0m. till 21h. 30m. G.M.T. The corona then faded, and aurora of the type known as "flaming" in Störmer's classification, with a period of 1 second, was observed for a few minutes. Activity continued, with rays and pulsating surfaces, till shortly after 22h., when cloud prevented further observation. The greatest intensity was at 21h. 42m.

On the night of the 24th–25th aurora was seen until 3h. from several places in the east and north of Scotland, including Lerwick, and until daylight from Dunnet Head Lighthouse (Caithness). From Leuchars, Mr. A. Simpson of the Meteorological Office reports that at 22h. 45m., when the clouds broke, there was an almost perfect corona of white rays overhead. A curtain of

white rays extended northwards and spread till it reached from west round to east. The corona moved eastward and faded soon afterwards. At 23h. 30m. the curtain in the north became very bright and of a faint green colour; five minutes later another white corona formed overhead, moved away to the east and faded, while the curtain increased in intensity and became reddish in tinge. A corona formed again a little to the west at 23h. 50m., very bright and faintly green, extending westward to a homogeneous arc at an elevation of about 20°. At this time aurora was first seen at Holyhead, where Mr. Forbes-Bentley of the Meteorological Office reports that there was a steady white arc from about west to north-east. Cloud then began to interfere with observations at Leuchars, but there were signs of activity until 1h. G.M.T.

At Holyhead conditions were perfect after 1h. 15m. At about this time flaming aurora was seen, the waves occurring at the rate of nine per second. The flaming continued until after 3h., with maximum intensity at 2h. 0m.

A report from Mr. E. L. Hawke says that at 3h. 5m. G.M.T. on the same morning the Rev. H. E. Ruddy of Aston Clinton Rectory, near Aylesbury, Bucks, saw a broad upright streamer about 15° west of north and a few minutes later a second thinner streamer beside it at 20° west of north.

On April 26th two large sunspots passed the sun's central meridan.*

D. N. HARRISON.

Severe thunderstorms with heavy rain on June 19th, 1256

Matthew Paris gives us the following account:—

And the third day following, an extraordinary storm of wind and rain, or rather driving rain, with hail and thunder and vivid lightning, filled the souls of men with fear and immense damage was sustained through the disturbance. The mill wheels were seen to be wrenched

* *Nature*, Vol. 143, p. 717 (April 29th, 1939).

off their axles, and transported by the force of the waters to great distances, destroying neighbouring houses. And what the waters did to the water mills, the wind did not spare to do to the windmills. The piles of bridges, stacks of hay, huts of fishermen, with their nets and poles, and even babies in cradles were suddenly carried away, so that it looked as if the floods of Deucalion were come again. And not to mention other cases, Bedford, which is watered by a river called Ouse, as it did a few years before, suffered damage beyond estimation. Indeed, in one place, a block of six adjacent houses was transported by the rapid torrents, the inhabitants hardly being able to crawl out of them. And other places on the banks of this river were exposed to similar perils.

C. E. BRITTON.

Sunshine, May 1939

The distribution of bright sunshine for the month was as follows:—

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	175	− 4	Chester ..	189	+23
Aberdeen ..	160	−10	Ross-on-Wye	194	+ 8
Dublin ..	194	+14	Falmouth ..	240	+33
Birr Castle ..	189	+20	Gorleston ..	210	−13
Valentia ..	255	+71	Kew.. ..	194	− 4

Kew temperature, mean, 53·2° F. : diff. from average, −1·3° F.

OBITUARY

SIR FRANK DYSON, D.Sc., F.R.S. It is with much regret that we announce the death on May 25th, 1939, of Sir Frank Dyson, Astronomer Royal at Greenwich, 1910–33. Sir Frank had been associated with Greenwich Observatory since 1894 when he was appointed chief assistant. In 1905 he became Astronomer Royal for Scotland, and held that post until he returned to Greenwich in 1910. The work of Greenwich Observatory was extended in various new directions under Dyson's

administration, and he took especial care that the observational work was of the highest quality. One aspect of his work that interested him greatly and which had wide public attention was the research on solar eclipses, and the expeditions arranged in connection with these, notably those of 1919 and 1927. His " Eclipses of the Sun and Moon " written in collaboration with Dr. R. Woolley, published in 1937, is the standard work on the subject. Another of his interests was time-keeping and the craft of clock-making; he initiated the " six-pips " time signal now so well known to listeners. Sir Frank was for many years a fellow of the Royal Meteorological Society and the meteorological work at Greenwich was continued under his directorship on the well-established lines subsisting from the days of Airy and Glaisher. He was a man of engaging personality and his charm of manner and gentle humour will long be remembered by those who had the privilege of associating with him.

Mr. C. L. Brook, who died on May 9th, 1939, in his 84th year, started a rainfall record at Harewood Lodge, Meltham, Yorkshire, in 1881 and a second record on the moors at Royd Edge in 1891. His rainfall record at Harewood Lodge covers therefore over 58 years. In addition earth thermometer records were forwarded for publication in the *Meteorological Record* of the Royal Meteorological Society from 1899 to 1911 and general meteorological observations were published in the *Monthly Weather Report* from 1912 up to date.

Mr. Brook was one of the Trustees of the British Rainfall Organization from 1910 until it was taken over by the Government in 1919. The following comments are quoted from Dr. Mill's article in *British Rainfall*, 1909, p. 36: " It appeared to me that the first Trustees of the British Rainfall Organization should be chosen from amongst the rainfall observers, especially from those who were intimately acquainted with the work of the organization . . . . The nine Observers who have

joined me as Trustees are known to most of my readers . . . . Mr. C. L. Brook was an old friend of Mr. Symons, and one of the most liberal supporters of the Rainfall Organization; he represents in a special sense the north of England."

With the death of Mr. Brook we lose one of our few remaining links with G. J. Symons and the pioneers in the study of British Rainfall.

CHARLES WEBSTER. We regret to learn of the death on May 9th of Mr. Charles Webster in his 81st year. Mr. Webster was formerly head gardener to the Duke of Richmond and Gordon and maintained full climatological observations at Gordon Castle, Morayshire, from 1891 until his retirement in 1937. His meteorological observations actually covered the long period of 58 years as he assisted his father who had charge of the station from 1879. Mr. Webster's capabilities as a grower and judge, especially in the culture of fruit, were widely recognised.

REVIEWS

British Health Resorts. (Official Handbook of the British Health Resorts Association) London, 1939. $9\frac{1}{2} \times 6$, pp. 320, illus. Price 2*s*. 6*d*. net.

Our varied coasts, looking west to the Atlantic, or east and north to the North Sea, and south to the Channel, provide a great variety of climates. Inland we have a number of spas and hot springs, such as Bath, and some bracing hill stations, and the seeker after health, whether holiday-maker or invalid, has a wide choice from which to satisfy his individual requirements. The British Health Resorts Association is doing a great public service by making readily available, in its Official Handbook, climatological data and medical information for a wide range of these resorts. The Association is a purely voluntary body, including many well-known doctors, and the medical parts of the Handbook are revised by a

representative Medical Advisory Committee. The Handbook deals first with the spas, then with the seaside resorts in alphabetical order, next with some inland resorts and finally with the healthful attractions of Australia, Cyprus and South Africa. The climatological statistics are mostly those of interest to invalids, being limited to the winter months (November to March), while the temperatures are expressed as the numbers of "outdoor" and "indoor" days. The figures show that quite a number of places in Great Britain are suitable for winter resorts. There are interesting articles by Mr. Bonacina on "Climate, health and the British resorts" and by the Editor, Dr. R. Fortescue Fox, on "The climates of the British coast."

Meteorological Organization for Airmen. New Delhi, India, Met. Dept., M.O.A. Pamphlet, 1939.

Meteorological services are among the essential ancillary facilities necessary for safe air navigation. The keenness of a government's perception of the importance of air services may be judged by the nature of the facilities provided and on this basis it appears that the Government of India is very wide awake to the value to that great country and the Empire of the new means of transport. Details of the comprehensive meteorological facilities provided for both private and air-line pilots in India are given in this pamphlet. A notable advance since the publication of the 1937 edition is the change from the use of local forms to international forms of messages and altogether the India Meteorological Department is to be congratulated on the form and substance of this pamphlet, which with its appendices runs to 66 pages and includes a map indicating the position and type of numerous meteorological stations.

J. S. F.

Rainfall : May 1939 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square	1·33	76	*Warw*	Birminghm, Edgbaston	1·09	51
Surrey	Reigate, Wray Pk. Rd.	1·58	87	*Leics*	Thornton Reservoir	1·50	75
Kent	Tenterden, Ashenden	1·56	99	,,	Belvoir Castle	1·11	53
,,	Folkestone, I. Hospital	1·38	..	*Rutl'd*	Ridlington	·74	37
,,	Margate, Cliftonville	2·01	127	*Lincs*	Boston, Skirbeck	·81	46
,,	Edenb'dg., Falconhurst	1·45	78	,,	Cranwell Aerodrome	1·01	56
Sussex	Compton, Compton Ho	1·63	73	,,	Skegness, Marine Gdns	·66	39
,,	Patching Farm	1·28	69	,,	Louth, Westgate	1·24	61
,,	Eastbourne, Wil. Sq.	·97	58	,,	Brigg, Wrawby St.	1·29	..
Hants	Ventnor, Roy.Nat.Hos.	1·56	92	*Notts*	Mansfield, Carr Bank	1·29	61
,,	Southampton, East Pk	1·30	65	*Derby*	Derby, The Arboretum	·98	49
,,	Ovington Rectory	1·17	54	,,	Buxton, Terrace Slopes	1·47	47
,,	Sherborne St. John	1·37	71	*Ches*	Bidston Obsy	1·30	68
Herts	Royston, Therfield Rec	1·93	99	*Lancs*	Manchester, Whit. Pk.	1·91	90
Bucks	Slough, Upton	1·66	99	,,	Stonyhurst College	1·01	35
Oxford	Oxford, Radcliffe	1·18	63	,,	Southport, Bedford Pk	1·14	55
N'hant	Wellingboro, Swanspool	·83	43	,,	Ulverston, Poaka Beck	·68	21
,,	Oundle	·57	..	,,	Lancaster, Greg Obsy.	1·30	52
Beds	Woburn, Exptl. Farm	1·26	65	,,	Blackpool	·76	35
Cambs	Cambridge, Bot. Gdns.	·92	52	*Yorks*	Wath-upon-Dearne	1·47	72
,,	March	·73	42	,,	Wakefield, Clarence Pk.	1·86	94
Essex	Chelmsford, CountyGns	1·85	128	,,	Oughtershaw Hall	1·18	..
,,	Lexden Hill House	1·37	..	,,	Wetherby, Ribston H.	..	..
Suff	Haughley House	·68	..	,,	Hull, Pearson Park	1·53	79
,,	Rendlesham Hall	..	..	,,	Holme-on-Spalding	1·91	95
,,	Lowestoft Sec. School	·61	38	,,	Felixkirk, Mt. St. John	1·75	93
,,	Bury St. Ed., WestleyH	1·16	64	,,	York, Museum	1·37	69
Norf.	Wells, Holkham Hall	·59	37	,,	Pickering, Houndgate	1·65	84
Wilts	Porton, W.D. Exp'lStn	·99	58	,,	Scarborough	1·62	85
,,	Bishops Cannings	1·48	76	,,	Middlesbrough	1·48	77
Dorset	Weymouth, Westham	·99	61	,,	Baldersdale, Hury Res.	·71	28
,,	Beaminster, East St	·70	34	*Durhm*	Ushaw College	1·10	51
,,	Shaftesbury	·92	..	*Norl'd*	Newcastle, Leazes Pk.	1·20	61
Devon	Plymouth, The Hoe	1·07	52	,,	Bellingham, Highgreen	·77	32
,,	Holne, Church Pk.Cott	·78	25	,,	Lilburn Tower Gdns.	1·12	48
,,	Teignmouth, Den Gdns	·41	22	*Cumb*	Carlisle, Scaleby Hall	2·09	87
,,	Cullompton	·60	28	,,	Borrowdale, Seathwaite	..	..
,,	Sidmouth, U.D.C.	·90	..	,,	Thirlmere, DaleHeadH.	1·63	34
,,	Barnstaple, N. Dev.Ath	1·06	51	,,	Keswick, High Hill	·79	25
,,	Dartm'r, Cranmere P'l	1·60	..	,,	Ravenglass, The Grove	·44	16
,,	Okehampton, Uplands.	·77	29	*West*	Appleby, Castle Bank.	·70	32
Cornw	Redruth, Trewirgie	1·39	60	*Mon*	Abergavenny, Larchf'd	·70	26
,,	Penzance, MorrabGdns	·78	35	*Glam*	Ystalyfera, Wern Ho.	1·09	31
,,	St. Austell, Trevarna	2·11	87	,,	Treherbert, Tynywaun	1·36	..
Soms	Chewton Mendip	1·03	37	,,	Cardiff, Penylan	·83	34
,,	Long Ashton	·89	42	*Carm*	Carmarthen, M.&P.Sc.	1·90	67
,,	Street, Millfield	·56	30	*Card*	Aberystwyth	1·78	..
Glostr	Blockley	·94	..	*Radn'r*	Bir. W. W. Tyrmynydd	1·25	36
,,	Cirencester, Gwynfa	·90	44	*Mont*	Lake Vyrnwy	1·12	36
Here	Ross-on-Wye	·70	33	*Flint*	Sealand Aerodrome	1·64	90
,,	Kington, Lynhales	·69	29	*Mer*	Blaenau Festiniog	1·26	24
Salop	Church Stretton	1·01	..	,,	Dolgelley, Bontddu	1·12	34
,,	Shifnal, Hatton Grange	1·23	60	*Carn*	Llandudno	·77	43
,,	Cheswardine Hall	1·17	53	,,	Snowdon, L. Llydaw 9	2·40	..
Worc	Malvern, Free Library.	1·02	47	*Angl*	Holyhead, Salt Island.	·66	34
,,	Ombersley, Holt Lock.	1·08	53	,,	Lligwy	·59	..
Warw	Alcester, Ragley Hall.	·86	42	*I.Man*	Douglas, Boro' Cem.	·65	26

Rainfall: May 1939: Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern.	St.PeterP't.GrangeRd.	1·10	65	*R&C.*	Stornoway, C.G.Stn.	1·20	49
Wig	Pt. William, Monreith	1·00	43	*Suth*	Lairg	·98	39
,,	New Luce School	1·29	45	,,	Skerray Borgie	1·02	..
Kirk	Dalry, Glendarroch	1·02	32	,,	Melvich	1·16	57
Dumf.	Eskdalemuir Obs.	1·20	36	,,	Loch More, Achfary	1·79	41
Roxb	Hawick, Wolfelee	1·25	53	*Caith*	Wick	·78	38
,,	Kelso, Broomlands	·67	35	*Orkney*	Deerness	·69	35
Peebs	Stobo Castle	·86	38	*Shet*	Lerwick Observatory	1·09	52
Berw	Marchmont House	·87	35	*Cork*	Cork, University Coll.	1·08	48
E.Lot.	North Berwick Res.	·82	41	,,	Roches Point, C.G.Stn.	1·20	49
Midl	Edinburgh, Blackfd. H	·97	47	,,	Mallow, Waterloo	1·05	47
Lanark	Auchtyfardle	·50	..	*Kerry*	Valentia Observatory	1·78	56
Ayr	Kilmarnock, Kay Park	·84	..	,,	Gearhameen	2·70	51
,,	Girvan, Pinmore	1·15	39	,,	Bally McElligott Rec.	1·25	..
,,	Glen Afton, Ayr San.	·77	26	,,	Darrynane Abbey	1·58	53
Renf	Glasgow, Queen's Park	·84	34	*Wat*	Waterford, Gortmore	1·01	44
,,	Greenock, Prospect H.	1·41	43	*Tip*	Nenagh, Castle Lough	1·62	66
Bute	Rothesay, Ardencraig	1·38	46	,,	Cashel, Ballinamona	1·31	56
,,	Dougarie Lodge	1·25	45	*Lim*	Foynes, Coolnanes	·62	27
Argyll	Loch Sunart, G'dale	2·69	75	,,	Limerick, Mulgrave St.	1·47	62
,,	Ardgour House	2·82	..	*Clare*	Inagh, Mount Callan	1·54	..
,,	Glen Etive	2·43	49	*Wexf*	Gorey, Courtown Ho.	1·51	68
,,	Oban	1·45	..	*Wick*	Rathnew, Clonmannon	1·37	..
,,	Poltalloch	1·67	58	*Carlow*	Bagnalstown FenaghH	·86	35
,,	Inveraray Castle	1·61	41	,,	Hacketstown Rectory	·86	33
,,	Islay, Eallabus	1·22	46	*Leix*	Blandsfort House	1·31	54
,,	Mull, Benmore	4·95	66	*Offaly*	Birr Castle	1·33	60
,,	Tiree	1·19	48	*Kild*	Straffan House	..	..
Kinr	Loch Leven Sluice	1·71	70	*Dublin*	Dublin, Phoenix Park	·67	32
Fife	Leuchars Aerodrome	1·31	67	*Meath*	Kells, Headfort	1·27	47
Perth	Loch Dhu	1·35	30	*W.M*	Moate, Coolatore	·79	..
,,	Crieff, Strathearn Hyd.	1·37	55	,,	Mullingar, Belvedere	1·15	47
,,	Blair Castle Gardens	·99	49	*Long*	Castle Forbes Gdns	1·24	48
Angus	Kettins School	1·91	71	*Galway*	Galway, Grammar Sch.	1·19	48
,,	Pearsie House	1·42	..	,,	Ballynahinch Castle	1·97	55
,,	Montrose, Sunnyside	1·24	61	,,	Ahascragh, Clonbrock	1·30	47
Aberd.	Balmoral Castle Gdns.	·95	41	*Rosc*	Strokestown, C'node	1·03	43
,,	Logie Coldstone Sch	·79	31	*Mayo*	Blacksod Point	1·74	62
,,	Aberdeen Observatory	1·13	48	,,	Mallaranny	1·72	..
,,	New Deer SchoolHouse	·97	44	,,	Westport House	·90	32
Moray	Gordon Castle	·97	46	,,	Delphi Lodge	3·71	61
,,	Grantown-on-Spey	1·02	44	*Sligo*	Markree Castle	·90	32
Nairn.	Nairn	·71	39	*Cavan.*	Crossdoney, Kevit Cas.	1·05	..
Inv's	Ben Alder Lodge	1·23	..	*Ferm*	Crom Castle	1·41	51
,,	Kingussie, The Birches	·63	..	*Arm'h*	Armagh Obsy	1·26	53
,,	Loch Ness, Foyers	·97	40	*Down.*	Fofanny Reservoir	2·40	..
,,	Inverness, Culduthel R	·83	45	,,	Seaforde	1·56	59
,,	Loch Quoich, Loan	3·50	..	,,	Donaghadee, C. G. Stn.	1·37	60
,,	Glenquoich	2·01	37	*Antrim*	Belfast, Queen's Univ	·82	35
,,	Arisaig House	1·87	54	,,	Aldergrove Aerodrome	·83	37
,,	Glenleven, Corrour	1·38	36	,,	Ballymena, Harryville	1·56	55
,,	Ft. William, Glasdrum	1·91	..	*Lon*	Garvagh, Moneydig	1·05	..
,,	Skye, Dunvegan	2·23	..	,,	Londonderry, Creggan	1·37	52
,,	Barra, Skallary	1·02	..	*Tyrone*	Omagh, Edenfel	·99	38
R&C.	Tain, Ardlarach	·48	21	*Don*	Malin Head	1·31	53
,,	Ullapool	·73	29	,,	Dunfanaghy	1·18	52
,,	Achnashellach	2·40	54	,,	Dunkineely	1·72	..

Climatological Table for the British Empire, December 1938

STATIONS.	PRESSURE. Mean of Day M.S.L.	PRESSURE. Diff. from Normal.	TEMPERATURE. Absolute. Max.	TEMPERATURE. Absolute. Min.	TEMPERATURE. Mean Values. Max.	TEMPERATURE. Mean Values. Min.	TEMPERATURE. Mean Values. ½ Max. and Min.	TEMPERATURE. Mean Values. Diff. from Normal.	TEMPERATURE. Mean. Wet Bulb.	Relative Humidity.	Mean Cloud Am'nt	PRECIPITATION. Am'nt.	PRECIPITATION. Diff. from Normal.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	0–10	in.	in.			
London, Kew Obsy	1011·3	− 2·4	55	21	44·4	35·2	39·8	− 1·6	37·7	87	7·6	3·29	+ 1·00	19	1·6	20
Gibraltar	1015·9	− 4·4	67	39	58·7	48·9	53·8	− 2·2	49·3	79	5·0	7·55	—	14	—	—
Malta	1011·9	− 4·3	65	43	61·3	53·5	57·4	− 0·5	52·8	74	6·0	4·37	+ 0·66	19	6·3	65
St. Helena	1015·5	− 1·5	67	53	63·0	56·4	59·7	− 1·2	57·5	93	9·8	3·30	+ 1·97	26	—	—
Freetown, Sierra Leone	1010·7	+ 1·5	90	72	87·3	75·1	81·2	—	73·1	85	5·9	0·02	− 1·40	1	—	—
Lagos, Nigeria	1009·3	− 0·7	89	70	87·7	73·2	80·5	− 1·3	76·1	91	5·3	0·16	− 0·65	2	7·7	66
Kaduna, Nigeria	1009·5	—	96	55	92·2	60·7	76·5	+ 2·2	59·4	38	2·0	0·01	+ 0·01	1	9·9	86
Zomba, Nyasaland	1006·7	− 1·8	86	62	79·7	65·6	72·7	− 0·4	69·4	84	8·0	14·12	+ 3·25	24	—	—
Salisbury, Rhodesia	1009·9	− 1·2	81	55	76·0	60·1	68·1	− 1·5	62·3	78	8·7	9·59	—	21	4·1	31
Cape Town	1014·1	− 0·2	86	48	76·9	57·9	67·4	− 0·5	59·5	63	2·3	1·21	+ 0·40	4	—	—
Johannesburg	1009·7	− 0·7	83	50	74·6	55·2	64·9	− 0·6	58·2	75	7·2	9·33	+ 3·90	19	6·6	48
Mauritius	1014·2	+ 0·5	89	65	84·4	69·6	77·0	− 1·3	71·1	65	5·3	1·74	− 2·94	16	8·7	65
Calcutta, Alipore Obsy.	1014·2	− 1·5	84	50	80·2	54·3	67·3	+ 0·8	55·7	84	0·7	0·00	− 0·24	0*	—	—
Bombay	1011·9	− 1·6	93	66	87·4	69·6	78·5	+ 1·1	66·7	69	3·0	0·00	− 0·05	0*	—	—
Madras	1012·8	− 0·7	86	63	83·3	69·1	76·2	− 0·5	69·7	78	5·8	2·34	− 3·01	2*	—	—
Colombo, Ceylon	1009·7	− 0·6	90	70	86·1	72·7	79·4	− 0·1	73·9	76	5·5	4·63	− 0·49	14	6·7	57
Singapore	1008·9	− 0·8	90	73	85·7	74·2	79·9	0·0	76·4	76	7·8	10·78	+ 0·22	20	4·7	39
Hongkong	1018·1	− 1·6	78	51	69·5	60·9	65·2	+ 2·2	59·3	69	7·7	0·01	− 1·02	0	4·0	37
Sandakan	1007·6	—	87	72	84·7	74·6	79·7	− 0·5	76·2	89	9·0	19·96	+ 1·32	26	—	—
Sydney, N.S.W.	1011·3	− 0·6	98	54	79·8	63·0	71·4	+ 1·3	63·3	52	5·5	0·46	− 2·40	3	8·8	61
Melbourne	1012·4	− 0·3	97	46	75·9	53·5	64·7	− 0·1	55·3	47	6·9	0·69	− 1·58	6	7·6	51
Adelaide	1014·2	+ 0·9	103	47	83·9	57·3	70·6	− 0·5	58·8	36	5·9	0·49	− 0·54	4	9·3	65
Perth, W. Australia	1012·7	− 0·5	98	50	80·6	61·1	70·9	+ 0·1	62·3	51	4·5	0·25	− 0·31	5	10·2	72
Coolgardie	1010·5	− 0·7	107	52	92·8	63·7	78·3	+ 2·6	64·6	52	3·2	0·64	− 0·05	3	—	—
Brisbane	1012·7	+ 0·7	102	61	86·4	69·3	77·9	+ 1·5	70·0	60	4·1	0·41	− 4·48	2	10·6	77
Hobart, Tasmania	1006·0	− 3·7	88	41	67·6	48·0	57·8	− 2·4	51·6	57	6·3	2·27	+ 0·28	17	8·0	52
Wellington, N.Z.	1004·9	− 7·3	71	44	62·9	50·4	56·7	− 3·5	54·4	75	7·8	7·41	+ 4·19	16	6·2	41
Suva, Fiji	1008·5	− 0·1	89	69	83·9	73·5	78·7	− 0·3	74·9	84	7·9	30·52	+18·00	26	4·2	32
Apia, Samoa	1008·8	+ 0·5	86	72	84·6	75·0	79·8	+ 0·5	76·7	80	6·7	20·94	+ 7·05	27	7·7	60
Kingston, Jamaica	1013·1	− 0·9	91	66	87·4	69·5	78·5	+ 0·8	67·0	80	1·3	0·10	− 1·49	3	7·5	68
Grenada, W.I.	1011·5	− 0·3	89	70	87	73	80	+ 1·8	73	74	7	9·17	+ 1·97	20	—	—
Toronto	1016·9	− 0·7	51	9	36·0	25·8	30·9	+ 3·8	27·7	76	8·7	2·23	− 0·24	22	2·0	22
Winnipeg	1016·1	− 2·6	36	−35	17·3	3·6	10·5	+ 4·7	—	—	6·3	1·18	+ 0·24	10	2·3	28
St. John, N.B.	1015·4	+ 1·4	54	0	35·0	21·5	28·3	+ 3·9	24·2	81	6·8	4·58	+ 0·41	15	3·1	34

Climatological Table for the British Empire, Year 1938

STATIONS.	PRESSURE. Mean of Day M.S.L.	PRESSURE. Diff. from Normal.	TEMPERATURE. Absolute. Max.	TEMPERATURE. Absolute. Min.	TEMPERATURE. Mean Values. Max.	TEMPERATURE. Mean Values. Min.	TEMPERATURE. Mean Values. ½ Max. and Min.	TEMPERATURE. Mean Values. Diff. from Normal.	TEMPERATURE. Mean Wet Bulb.	Relative Humidity.	Mean Cloud Am'nt	PRECIPITATION. Am'nt.	PRECIPITATION. Diff. from Normal.	PRECIPITATION. Days.	BRIGHT SUNSHINE. Hours per day.	BRIGHT SUNSHINE. Percentage of possible.
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	0–10	in.	in.			
London, Kew Obsy	1016·9	+1·5	84	21	58·4	45·1	51·7	+1·5	46·3	84	7·5	18·15	−5·65	140	4·0	33
Gibraltar	1018·2	—	97	35	67·2	57·4	62·3	−1·9	56·5	80	4·8	22·33	—	68	—	—
Malta	1016·5	−1·2	101	42	69·4	59·9	64·6	−1·5	59·0	75	4·3	27·98	+8·12	92	8·6	71
St. Helena	1017·3	−0·9	75	51	64·3	57·4	60·8	—	58·5	93	9·1	34·32	+4·30	235	—	—
Freetown, Sierra Leone	1011·7	+1·9	92	68	85·6	74·0	79·7	—	74·3	83	6·3	128·62	−28·61	170	—	—
Lagos, Nigeria	1011·0	+0·1	92	73	85·5	74·0	79·8	−0·9	75·5	88	7·0	58·68	−13·30	120	5·6	46
Kaduna, Nigeria	1010·6	—	102	55	89·4	65·9	77·7	+0·6	65·9	74	5·6	47·13	−6·77	106	7·8	64
Zomba, Nyasaland	1012·1	−0·3	94	50	78·7	61·1	70·1	+0·7	66·5	79	5·8	68·00	+13·46	105	—	—
Salisbury, Rhodesia	1014·7	−0·7	91	34	76·7	53·7	65·2	−0·1	56·9	60	4·1	32·55	—	87	8·1	67
Cape Town	1017·3	+0·3	93	35	71·9	54·0	62·9	+0·6	55·9	79	4·4	25·15	+0·11	120	—	—
Johannesburg	1015·1	−1·8	88	29	70·9	50·2	60·5	+0·8	51·2	61	3·5	30·52	−2·70	99	8·2	68
Mauritius	1016·0	−0·1	90	52	80·7	67·5	74·1	+0·1	69·5	71	5·3	36·44	−13·31	208	8·1	67
Calcutta, Alipore Obsy.	1006·8	−0·8	107	50	88·8	71·6	80·2	+1·5	72·5	85	4·9	47·58	−16·74	76*	—	—
Bombay	1008·1	−1·1	94	60	86·2	73·8	80·0	−0·6	72·9	78	4·4	92·01	+19·82	97*	—	—
Madras	1007·9	−0·9	108	63	90·7	75·5	83·1	0·0	74·5	75	6·2	26·46	−23·10	38*	—	—
Colombo, Ceylon	1009·6	0·0	92	67	86·0	75·4	80·7	−0·3	76·4	76	6·6	64·76	−15·37	196	6·8	56
Singapore	1009·4	−0·1	94	70	86·2	75·5	80·8	−0·1	77·4	78	7·4	94·44	−0·68	200	5·6	46
Hongkong	1012·4	−0·2	94	47	77·9	69·3	73·6	+1·3	68·5	75	6·9	55·36	−30·37	128	5·4	45
Sandakan	1008·7	—	91	71	86·4	75·1	80·7	−0·5	76·7	86	8·0	173·32	+48·53	211	—	—
Sydney, N.S.W.	1015·9	0·0	98	37	71·8	56·9	64·3	+1·2	58·3	67	5·3	39·17	−8·31	132	6·6	54
Melbourne	1016·1	−0·2	103	29	69·4	49·6	59·5	+1·1	52·3	63	6·5	17·63	−7·84	132	5·6	46
Adelaide	1017·3	+0·2	107	36	73·4	52·9	63·1	+0·1	55·1	55	5·9	19·26	−1·89	119	6·6	54
Perth, W. Australia	1016·7	+0·3	103	41	73·3	55·3	64·3	+0·1	56·7	61	5·1	29·64	−4·73	109	8·1	67
Coolgardie	1016·0	+0·1	108	35	77·2	53·3	65·3	+0·7	56·0	63	3·6	8·14	−2·13	41	—	—
Brisbane	1016·0	+0·1	102	41	77·6	61·0	69·3	+0·4	62·9	69	5·0	43·49	−1·80	110	7·6	63
Hobart, Tasmania	1013·1	+0·6	92	33	62·5	46·8	54·7	+0·3	49·4	68	6·2	31·22	+7·43	169	5·7	47
Wellington, N.Z.	1015·8	+1·2	81	33	61·3	49·8	55·5	+0·2	53·1	79	7·3	58·20	+10·16	171	5·4	45
Suva, Fiji	1011·4	+0·1	92	62	83·5	72·9	78·2	+1·2	73·8	84	6·3	158·85	+41·71	260	5·0	41
Apia, Samoa	1010·2	−0·1	90	69	84·9	74·6	79·7	+1·2	76·2	79	5·8	139·45	+29·74	230	7·3	60
Kingston, Jamaica	1013·6	−0·1	93	63	87·3	71·1	79·2	−0·1	69·7	81	3·2	20·94	−12·65	60	7·0	58
Grenada, W.I.	1011·3	−1·1	90	70	86·2	72·9	79·5	+0·7	73·7	76	5·8	122·15	+47·56	252	—	—
Toronto	1016·7	+0·1	92	−5	56·4	40·3	48·3	+3·2	—	—	6·1	25·65	−5·64	154	5·4	44
Winnipeg	1015·8	−0·4	93	−41	48·8	27·3	38·1	+3·5	—	—	5·1	16·10	−4·08	109	5·7	46
St. John, N.B.	1016·2	+1·7	84	−12	50·1	35·3	42·7	+1·5	38·1	83	6·7	53·54	+5·46	187	5·1	42
Victoria, B.C.	1017·1	+0·5	84	28	56·4	44·3	50·4	+1·0	47·3	82	5·8	23·90	−6·41	145	6·7	55

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Daily Readings at Kew Observatory, May 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Wind, Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	Remarks.
	mb.			°F.	°F.	%	in.	hrs.	
1	1015·8	NNE	3	43	47	88	0·45	0·0	r_0–r 0h–11h & 14h–22h.
2	1014·7	NNE	4	42	50	71	0·02	0·1	d_0–d 19h–21h.
3	1015·7	NNE	3	41	54	55	—	7·1	
4	1011·0	S	3	37	56	64	—	5·2	
5	999·0	SSE	4	40	55	75	trace	1·5	pr_0 8h, 11h & 13h.
6	999·6	E	3	42	59	58	0·02	2·6	pr_0 t 16h, f–F 21h–24h.
7	1010·2	N	2	38	65	58	trace	9·9	F–f early.
8	1018·8	NW	2	44	67	50	—	12·4	
9	1024·2	Calm		46	68	51	—	8·8	
10	1025·6	NNE	3	49	68	64	—	3·7	
11	1025·9	NNE	5	52	60	63	—	4·7	
12	1019·8	N	4	43	53	72	0·02	1·4	r_0 7h–8h, id_0 13h–16h.
13	1020·3	NE	5	47	63	42	—	14·2	
14	1015·1	NNW	3	40	60	68	trace	2·7	ir_0 12h–17h.
15	1005·2	NNW	3	47	51	83	0·16	0·0	r_0–r 2h–4h & 18h–24h.
16	1007·1	NNE	5	45	57	55	0·46	1·0	r–r_0 0h–10h.
17	1003·9	N	2	45	53	83	0·26	0·0	r_0–r 0h–12h, r_0 16h.
18	1007·8	NNE	2	43	56	67	trace	0·0	id_0 about 7h.
19	1010·9	NE	2	45	57	47	—	8·7	
20	1012·6	SW	2	41	60	58	—	5·5	
21	1015·6	W	3	44	62	52	—	6·4	
22	1022·3	WSW	2	44	68	61	—	7·2	
23	1029·0	WSW	1	47	73	51	—	11·0	
24	1029·0	NW	2	48	74	35	—	11·9	
25	1029·0	N	3	56	64	66	trace	0·9	pr_0 14h & 15h.
26	1028·9	N	2	47	67	46	—	13·9	
27	1025·4	N	4	51	69	58	—	6·2	
28	1030·9	NNE	4	50	63	54	—	10·7	
29	1030·8	NE	3	45	66	56	—	12·0	
30	1028·4	NNE	4	48	65	52	—	12·1	
31	1024·5	NE	4	48	71	50	—	12·3	
*	1018·0	—		45	61	60	1·39	194·1	*Means or Totals.

General Rainfall for May 1939

	Per cent.
England and Wales	56
Scotland	44
Ireland	49
British Isles	52

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